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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Prof. J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*SPECIAL EXPLORATIONS IN THE IMPLEMENT-BEARING DEPOSITS ON THE LALOR FARM, TRENTON, N. J.**

BY permission of Professor F. W. Putnam a number of geologists and archæologists were invited by me to conduct independent investigations on the Lalor farm in Trenton, N. J., with a view to verifying the conclusions at which he had arrived concerning the age of the artifacts found in the gravel at that place. As a result of the invitation, Mr. H. C. Mercer, Professor Arthur Hollick, Dr. H. D. Kümmel and Professor William Libbey met with me upon the ground, and we availed ourselves of the facilities afforded us by Mr. Ernest Volk, who has been for several years engaged in explorations in the vicinity of Trenton, under the direction of Professor Putnam, in the interests of the Peabody Museum, Cambridge, Mass.; the Columbian Exposition, of Chicago, and the Museum of Natural History of New York City. I was upon the ground the 25th, the 26th and the 28th of June, and September 13th and 14th, 1897. At this time Mr. Mercer was present every day but the 13th of September, and Professor Hollick every day but the 28th of June and the 14th of September, while Dr. Kümmel and Professor Libbey were present for only a single day.

* This paper will be followed by others on the same subject.—ED.

The farm on which such generous privileges have been granted by the Misses Lalor is situated on the terrace upon which the city of Trenton is built, about a mile below the city, overlooking the Delaware river from the edge of the terrace, which here descends abruptly to the flood-plain of the Delaware, about forty feet below. That this farm is within the limits of the so-called 'Trenton gravel' is conceded by every one, and is clearly evident from a gravel pit which has been recently opened not more than three hundred yards to the north. In this pit, which has been worked to a depth of about twenty feet, the general sand and gravel are very distinctly stratified, with the lines of bedding and cross-bedding perfectly distinct up to within three or four feet of the surface. Many boulders, some of them two or three feet in diameter, occur in the lower part of the deposits. A large pile of boulders which had been thrown aside by the workmen well illustrates the observation early made by Professor Cook and Professor Shaler, that the material of the Trenton gravel is almost entirely derived from the upper part of the valley of the Delaware river, and is to that extent local material.

There is but one theory entertained by geologists at the present time concerning this gravel, which is, that it is a delta deposit made by the glacial floods which came down the river from the melting of the ice which formed the Belvidere terminal moraine, about seventy miles above Trenton. Through that distance the gradient of the river is about three and a-half feet to the mile, and the valley is narrow, so that the abundant floods of that time could easily bring down the excessive amount of *débris* released by the melting ice. On reaching tide-water and a broader valley at Trenton the swollen streams of that epoch rapidly built up the fifty-foot delta terrace upon which the city stands. This terrace is from two to three miles in diameter, upon the New Jersey side, and wherever excavated shows substantially the same phenomena described in the pit adjoining the Lalor farm, which is about the middle of the special enlargement of the deposit from north to south from which the gravel received its name.

The excavations made by our party were upon the summit of this delta deposit, beginning from the bluff where it faces the river valley to the west, and which breaks down to the level of the flood-plain, forty feet below, with as steep a descent as the gravel would naturally maintain, the slope being now covered with a luxuriant growth of forest trees.

As our investigations were made with reference to verifying the conclusions of Mr. Ernest Volk, it is proper to state the main results of his work. Mr. Volk has carefully dug over the area stretching back from this bluff for a width of about three hundred feet and a length of something like twenty-five hundred feet. Over all this area he has sunk trenches a little over three feet in depth, and carefully noted the evidences of human occupation, together with the character of the deposit and the depth at which the artificial objects have occurred. All this material gathered by him is to be found carefully labelled, but for the most part unreported upon, in the museums above referred to in our first paragraph. Mr. Volk's work has shown that the upper twelve inches of this surface contains more or less signs of vegetable mould, and a very large number of chips and chipped implements made from flint and jasper, with occasional chipped pieces of argillite. Many other indications of the ordinary occupation by Indians also occur in this upper foot of soil; such as pieces of pottery, the bones of animals which had been used for food, and pieces of charcoal. Occasionally, also, there are pits running to a depth of two or

three feet in which are similar objects down to the bottom.

But in the compact undisturbed sand from one foot below the surface through the two feet or more of the lower part of the trenches Mr. Volk reports that he has found no pottery or charcoal or chipped fragments of jasper, flint or quartz; but that he has found, sparingly scattered throughout the entire mass, many chipped fragments and implements made from argillite, these occurring frequently near the bottom of the trenches, three feet and more below the present surface and two or more feet below ordinary signs of recent disturbance.

At the first visit our own work consisted in the digging of one long trench from near the edge of the bluff back through a distance of twenty-one and a-half feet. Its width was three and three-quarters feet, and its depth a little over three feet. This was immediately north of the ground which has been explored by Mr. Volk. We also dug three other pits, one being about twenty feet farther north, which was $7\frac{3}{4} \times 4\frac{1}{2}$ feet; another, thirty feet east of the second, which was six feet square; a fourth, one hundred feet still farther east, and on ground about one foot higher, which was four and a-half feet square.

After careful examination we fixed upon fifteen inches as the limit of probable or possible ordinary disturbance, and had all the superincumbent soil removed from the trenches to that depth. We then had narrow excavations made two feet lower or to a total depth of forty inches, in some cases going still farther down. Having prepared a smooth perpendicular surface, the work was subsequently done by carefully scraping off the face of the excavation with a trowel, and when any object of stone was encountered, all were called to witness it in place before removal. In this way a total amount of three hundred and twenty-five cubic feet of the deposit was carefully examined. This is equivalent to a trench forty feet long, four feet wide and two feet deep; this being the lower two or more feet of the material removed.

Number of Objects Found.—As a result of this examination during the first visit, there were found in the lower two feet of undisturbed soil fifteen chipped fragments or implements of argillite all covered with a deep patina, two thick flakes of jasper and three of quartz, with a few broken stones. There were found and counted also between three hundred and four hundred pebbles ranging from the largest, which was $8\frac{1}{2} \times 4\frac{3}{4} \times 2\frac{1}{2}$ inches, down to numerous ones the size of a French pea. Many of them were from one to two inches in diameter. The implements were scattered pretty evenly through the entire mass of gravel. The upper five inches contained four; the second five, seven; the third five, four; the fourth five, five. Besides this there were six battered or broken pebbles, showing artificial origin, but all these were in the upper six inches of our stratum. Of the quartz and flint flakes, two were found in the upper four inches, two from ten to twelve inches down, and one at a depth of eighteen inches.

The Character of the Strata.—Beginning at the top, there is first a stratum of fifteen inches to be excluded. The upper seven inches of the stratum under consideration consists of compact sand in which there are no signs of bedding or disturbance of any sort.

Below this occurs, over most of the area, a reddish, clayey band, about a-half inch thick, which extends in a wavy line, often thinning out so as to be almost imperceptible.

Below this is a stratum of yellowish sand, similar to the first, about six inches thick.

Below this is a second continuous reddish band slightly waved, but far less so than

No. 1, and about two inches thick, thinning out, however, in places to half an inch or slightly less.

Then occurs another stratum of yellowish sand, about four inches thick.

Still lower comes reddish clay, * ten inches thick, partly divided by an irregular stratum of sand, two or three inches thick, running through the middle of it. In some places, however, the clay bands coalesce, and the sand continues along the line in lenticular masses. This clay stratum rests upon the more completely washed sand and gravels which form the great mass of the terrace.

Analysis of these Strata.—The predominant material in the entire thickness examined is sand, but there is mixed with it a varying amount of clay and iron, both being specially concentrated in the red bands. I have had specimens from these strata analyzed to determine the relative amount of clay, sand and iron contained in them. The specimens were first thoroughly and repeatedly soaked and shaken in water, which was poured off immediately, carrying everything which could be held in suspension, and leaving the sand thoroughly washed. After being allowed to settle twenty-four hours, the water was siphoned off and the residue thoroughly dried. This was then compared in bulk with the residue of sand which had also been dried. All the specimens were treated in a similar manner. The results were, beginning at the top:

1st sand stratum, 18% suspended matter; 2d sand, 16%; 3d sand, 14%; underlying sand, 7%. Of the red bands, 1st red stratum, 24% suspended matter; 2d red stratum, 27%; 3d stratum, 27%; 4th (or lower part of 3d) stratum, 37%. The amount of iron contained in the fine sediments so far as analyzed was as follows: from the 2d sand, one-half of one per cent. of the whole amount; of the 2d red stratum, one and one-half per cent. of the whole amount, and the same for the 4th red stratum. These red bands, therefore, are not to any appreciable extent segregations of iron. The iron scarcely more than suffices to give the color. The analysis shows, therefore, that these red bands contain from 25% to 33% more clay than is found in the interstratified strata of sand.

While the water-worn pebbles were distributed more or less through the entire mass, they are specially abundant in and below the second, third and fourth reddish clayey accumulations. These pebbles vary in size, as has been said, from those several inches in diameter down to small pieces of gravel. Pebbles from one to two inches are numerous. The largest one referred to was imbedded in the clayey stratum, No. 2, just as if dropped into the clay and pressed nearly through it, crowding lower down two or three smaller ones which underlay it. This was found in the longer trench, thirty-two inches below the surface, or seventeen inches below our selected zone of doubt. This was about three feet distant from the locality of one of our best-formed chipped argillite scrapers, which occurred three inches lower down in the deposit, and beneath the clayey stratum. As I personally removed with my trowel all material in this section, I know that the clayey stratum containing the large pebble was continuous and unbroken, not only between the pebble and the point directly over the argillite implement, but for two or three feet upon the other side, and that pebbles, large and small, were frequently struck by the trowel along the entire distance.

The implement above referred to was located carefully and photographed by us. The first clayey band over it was here about two inches thick and so compact as to give distinct special resistance to the trowel

* Throughout I use clay as signifying simply sediment so fine that it is held in suspension in water for an appreciable time.

wherever it was struck. Its level was twenty inches below our zone of doubt, or thirty-five inches below the surface. Upon our last visit, however, two well-formed argillite implements were found at still greater depth, and if possible in still more unequivocal position. One of these, found by Professor Hollick, was in the main trench more than twenty feet farther east. This was, also, below the second clayey band, which is here nearly ten inches thick. The implement was three feet five inches below the surface, or twenty-six inches below the arbitrary line we had fixed as our zone of doubt. The order of strata was as follows: one foot, disturbed soil; eighteen inches, compact yellow sand; first wavy reddish clayey band, one-half inch; yellow sand, two inches; second reddish clayey stratum, with inclosed lenticular sand patches, ten inches; sandy layer, five inches, containing the implement; reddish clayey band, five inches. Below this, without any signs of unconformity, were several successive alternating strata of sand and reddish clayey material to the total depth dug, six feet nine inches. There was every indication that the entire deposit up at least to the upper wavy reddish clayey stratum was built up by a continuous process of water deposition, the upper portion representing the waning cycles of deposition characteristic of floods which were reaching their limit both by reason of increased elevation of the flood-plain and of a diminution of the water supply.

Eight feet north of this implement, across the end of the trench, with the strata continuous between, Mr. Volk had previously photographed another argillite implement in place one inch lower than this and beneath almost exactly the same succession of strata. Again, on the face of one of our earlier pits farthest from the bank, about forty feet disant from this one, we found on the second visit and photographed, and Mr. Mercer took out with his own hands, a well-formed argillite implement three feet three inches below the surface, or two feet below our arbitrarily chosen line of doubt. There were two of the clayey bands above this, the order being closely similar to that described in the trench. The second of the clayey bands, which is here about two inches thick, contained a pebble more than two inches in diameter, which was pressed down into the stratum as if by its own and the superincumberent weight. On removing the pebble the clay adhered to it, but was not cemented to it. It could all easily be removed with the fingers. Two or three feet east of this implement were the marks of the tap-root of a tree which had penetrated all the strata to a depth of something over two feet. It was perfectly easy to distinguish the course of this root, but there were no other signs of such disturbance around the face of the exposure in the vicinity of any of the implements described.

Extent of the Reddish Clayey Bands.—To determine the extent of these deposits and the manner of their formation, pits were dug at three points, from two hundred to five hundred feet farther in from the edge of the bluff. Two of these were upon a slightly elevated ridge, from two to three feet higher than our main trench, being the highest portion of the plain. The other was in the center of a shallow basin, towards which there was a gradual slope in every direction, it being from two to three feet lower than the trench and about two hundred feet away. In all these pits the succession of strata was similar to those in the main trench, with this difference, however, that the reddish clayey bands were encountered several inches lower down in the center of the basinlike depression than upon the higher elevations. This effectually disposes of the theory that the slight irregularities in the surface were produced by wind action. If the elevations were wind accu-

mulations the sand would be thicker there than in the depressions, but the opposite was the case. The slight irregularities of the surface, therefore, are the result of original motor deposition and not of wind action.

Observations upon other portions of the delta terrace revealed the same condition of things. In the gravel pit already referred to, about three hundred yards to the north, the succession in the upper three or four feet exposed is substantially the same. The clayey bands are distinctly apparent, and the whole structure is conformable. In this pit there occurs, and was photographed by us, a thick deposit of fine sand near the bottom, containing thin wavy bands of stratified clay, very similar to the upper one described in our main trench. Again, about a mile distant, toward the southeast, near the park, an excellent exposure of the terrace shows the same succession. With this, also, agrees the description given by Mr. Volk of his explorations on the same terrace in 1891, at a point about half way between the park and the present explorations. (See Proceedings of the A. A. A. S., Vol. XLII., 1894.) In describing the strata, he says: "The soil in this place consists of nine inches of black or subsoil, tilled land, overlying an undisturbed sandy loam composed of quartz sand, colored by iron and mixed with a yellow soil, the sediment of muddy water, the whole having a light yellow color. Three feet below the surface is a somewhat uneven stratum of red clay mixed with sand."

From all this it is clear that this deposit, up at any rate to the upper line of reddish clayey band, is part and parcel of the Trenton gravel.

A most natural explanation of the deposition of these successive strata of sand and clayey bands is at hand in the closing floods of the glacial period which confessedly built up the terrace to within a few inches of several of the implements found in place. All the phenomena can easily be accounted for by the forces then known to be in operation. The floods accompanying the close of that stage of the glacial period which formed the terminal moraine crossing the river at Belvidere brought down the *débris* from the melting ice until the delta terrace was built up to a height of about forty-seven feet. This, all readily admit. But it is easy to see that as the delta grew higher, and the material accessible to floods diminished, the closing deposits would consist of finer material, the conditions being somewhat like those of ordinary flood-plains, only in this case the forces were more extraordinarily variable and vast in their proportions. In the last stages of this epoch we may well suppose that during the months of July, August and September the waters running over this delta terrace were occasionally swollen enormously, though the elevation overflowed was such that any large masses of boulder-laden ice were prevented from sweeping over it, such as did during the earlier stages of the deposit. These floods would easily distribute large quantities of sand along the edge of the terrace of the main stream, extending back for an indefinite distance or to the slightly higher deposits that had previously been made, and this under conditions so uniform that several inches might be accumulated without signs of bedding. On the subsidence of the floods the clayey strata would naturally accumulate, as shown in these deposits.

But how did the implements become incorporated in the strata? By a process which is perfectly natural and credible. During the larger part of the year, when the melting of the glacial ice was proceeding at a slow rate, vast bars and abandoned channels of the main pebbly deposits of sand and gravel would be exposed, affording to the aboriginal inhabitants a choice

field for procuring argillite boulders, with an occasional one of quartz or jasper, from which to make their favorite implements; while the conditions connected with the head of tide-water doubtless made it then, as later, a favorite hunting and fishing ground. Few things have ever impressed me so much as the abundance of life of all sorts at the head of the inlets, both in Alaska and Greenland, into which large glaciers pour their currents of ice-cold water. The implements and chips lost by the natives on these temporarily abandoned stretches of gravel and sand bordering the main current are the ones mingled with scattering pebbles which were swept into their present position upon the Lalor farm by the subsequent floods of the season.

But this condition of things did not remain long. After the flooded Delaware ceased to receive superabundant glacial *débris* and an excessive supply of water from the melting ice it not only ceased to build up the terrace, but began speedily to cut and enlarge its present channel, leaving the surface of the delta terrace forever after undisturbed by its action. The terrace is now about forty feet above the flood-plain. Thus we have a natural and perfectly credible method for accounting for the phenomena in question.

It is, however, not only incumbent to provide an adequate cause for such phenomena, but we are in duty bound to give sound reasons for excluding other hypotheses which may be supposed to account for the facts. One hypothesis is that the clay band No. 2 has been produced by segregation, and so may have been formed over the implements found underneath it since their deposition. But the stratum contains only a slight amount of iron in excess of that found throughout the entire sand deposit. There still remains the excessive amount of clay which characterizes the stratum. It can scarcely be possible that that was segregated over so extensive an area after the whole had been deposited. Besides there must be something to account for the slight excess of iron which characterizes the red stratum. It is not only slightly excessive in amount above what is found in the accompanying sand, but is different in color; that being yellow and this red.

The suggestion that this clayey stratum No. 2 is an old wind-blown surface encounters several insuperable objections.

1. Its extent and uniformity are greater than could be obtained by a wind accumulation.

2. It contains large numbers of pebbles too great for removal by winds. As already mentioned, one of these was several inches in its longest diameter, and many were over an inch in diameter. To the suggestion that these may have been brought upon the surface by human agencies at the same time that the chipped flakes were lost, it can be answered that many of these were too small to have offered any inducement to anybody to have brought them up into that place, and they are scattered through the formation so uniformly that they indicate distribution by natural agencies; while their occurrence in the clayey stratum points to water, and not to wind, for their distribution. Especially significant were the two or three small pebbles underneath the large one which lay as if pressed by the weight of the larger pebble into and almost through the clayey stratum.

To the suggestion that these pebbles had been brought up from the lower strata by overturning of trees, it is to be said that if that was the case it must have been before the formation of the clayey stratum since that by actual observation was continuous and undisturbed for a distance of many feet on either side of many of these pebbles.

To the theory which would account for the iron in the stratum through the oxida-

tion of the vegetable accumulation occurring upon the surface, it is to be replied that this would not account for the accumulation of clay, but rather it needs the accumulation of clay to arrest the soluble iron in its downward progress. Whatever may be true of that upper and more wavy film of reddish material, it cannot well be maintained that stratum No. 2 is of a different origin from that of the thicker strata 3 and 4, the last of which rests directly on the acknowledged glacial gravel. In case of these it cannot be maintained that they are the results of a progressive oxidation proceeding from the surface downwards, since they are distinctly separated by the strata of yellow sand. There must have been something in the original deposition to have determined the relation of these differently colored strata to each other, and that original stratification has not been to any great extent disturbed by subsequent agencies.

If these red bands are the results of oxidizing agencies connected with vegetable deposits, they must still be placed long anterior to the accumulation of vegetable mould which is now upon the surface; for in many cases Indian pits are found in which the vegetable mould is entirely unaffected by oxidizing agencies; and, as this farm is known to have been occupied by the whites two hundred years, we have a partial measure of the slowness with which vegetable matter decomposes in this soil.

Furthermore, if the action of tree roots, worms and other small animals were so great in breaking up and destroying the lines of stratification two or three feet below the surface, as some have supposed, these clayey strata must be very recent, else they would have been completely obliterated. But their integrity is a complete answer to the theory that the soil down to a depth of four feet is everywhere necessarily disturbed through the lapse of long periods of time. In the present case every attempt to account for the clayey strata 2, 3 and 4 otherwise than by the agency of water is beset with insuperable difficulties. There are none of the marks of those other supposed agencies left to indicate their activity. Whereas, with the acknowledged floods of water rising to within a few inches of these deposits, it is easy to believe in the extension of this agency in building up the deposits of the superincumbent fifteen inches. If any one denies this natural and easy explanation he is bound to bring forth reasonable evidence to the contrary. To adduce complicated hypotheses involving inadequate and unknown causes of which there are no signs present, is not sufficient.

The evidence that the implements found below stratum No. 2, forty-one inches below the present surface, and only five inches above the action of acknowledged glacial floods, belong to the deposits of the glacial floods is sufficient, I believe, to convince any one who comprehends all the facts. At any rate, it is in the highest degree hazardous to assert that the problem of their age is insoluble, and that no trustworthy inference concerning it is possible. For a short time the facts can remain open for the observation of others. Let any one who is in doubt visit the locality and see for himself.

Professor Libbey of Princeton University spent the afternoon of September 14th with us on the ground when all the exposures were open to inspection. These he photographed and carefully examined with reference to all the questions involved. In respect to them he writes as follows: "Princeton, September 20, 1897. I take pleasure in putting on record my opinion with reference to the deposits which we studied together last week. There is no doubt in my mind as to the origin of the deposits in which the various implements were found. The lower gravel layer immediately below is undoubtedly due to

water action, and I cannot believe that the banded region composed of sand heavily mixed with clay could have been laid down in any other way than those just below. Certainly no wind action can ever be held responsible for such level and uniform deposits over such an area, but it might rather be explained by a change in level affecting the velocity of the current—in fact, I believe the existence of this bed can be explained only in this way."

G. FREDERICK WRIGHT.

OBERLIN, September 20, 1897.

PROFESSOR RUDOLPH HEIDENHAIN.

THE announcement of the death of Professor Rudolph Heidenhain, though not entirely unexpected, will call forth in physiological circles a note of deepest regret. It brings to memory the names of Brücke, Helmholtz, Karl Ludwig and Emil DuBois-Reymond, members of that coterie of brilliant scientists whose unusual ability for many years attracted to the German laboratories students of medicine from every part of the civilized world. And with these names are largely associated the remarkable transformation and progress which physiological science has experienced since the days of Johannes Müller.

Rudolph Peter Heinrich Heidenhain was sixty-three years of age at the time of his death, having been born Marienwerder, January 29, 1834. The elder Heidenhain was a physician, and it was not strange that the young man should inherit an enthusiasm for the natural sciences; it is told, in fact, that his interest in the work to which his life was devoted was early aroused by the reading of Volkmann's 'Haemodynamik,' which had just been added to the father's library. Heidenhain pursued the usual university medical studies at Königsberg, Halle and Berlin, receiving his degree at the latter place in 1854 with a dissertation entitled 'De nervis organisque centralibus cordis cordiumque ranae lympaticorum.' As assistant to Du-Bois-Reymond, the following three years were devoted to investigations in muscle physiology, a series of studies being published in 1856. In 1857 Heidenhain qualified at Halle as 'Privatdocent' in physiology, with a thesis entitled 'Disquisitiones criticae et experimentae de sanguinis quantitate in mammalium corporis exstantis'; two years afterward, in 1859, at the early age of twenty-five, he accepted the chair of physiology and histology at Breslau in Silesia, a position which he occupied until his death. Heidenhain obtained many official distinctions during his academic career, and among these the Harveian medal with which he seemed especially pleased; he was a member of numerous learned societies, and for many years enjoyed the title of 'Geheimer Medicinalrat.'

The advent of Heidenhain to Breslau and to the institution in which, years before, Purkinje had been active, was followed by a series of physiological researches continued almost uninterruptedly until the past year. These contributions have been marked not alone by the originality with which the subjects have been treated, but especially by a deep insight into the problems presented and a thoroughness of investigation and devotion of energy as untiring as it was characteristic. The results of these labors have had so important an influence in determining certain chapters of physiology as taught to-day that it may, perhaps, be permitted to present a few fragments of Heidenhain's work and to indicate their bearing.

In 1864 appeared the well known monograph on 'Mechanische Leistung, Wärmeentwickelung und Stoffumsatz bei der Muskelthätigkeit.' Helmholtz had shown that the tetanic contractions of a muscle, when continued for some minutes, are attended by a production of heat, but it re-